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(54) Improved antenna structure.

(57) An improved radio frequency antenna may be manufactured and assembled in a cost-effective manner using a pair of conductive sections. A first conductive section has alternating wide and narrow portions, and an opposing second conductive section has alternating wide and narrow portions which are arranged opposite the narrow and wide portions, respectively, of the first conductive section. The first and second conductive sections are secured together with a gap formed therebetween such that the first and second conductive sections form an elongated unit having a first end and a second end. Each end of the unit may be terminated using a shorting rod soldered between the first and second conductive sections, and a coaxial cable may be electrically coupled to the first and second conductive sections, near the middle of the unit, for coupling a radio frequency signal to the antenna. Alternatively, the unit may be terminated at only one end, and the other end of the unit may be used for interfacing to the coaxial cable. Further, a radome may be used to enclose the unit.

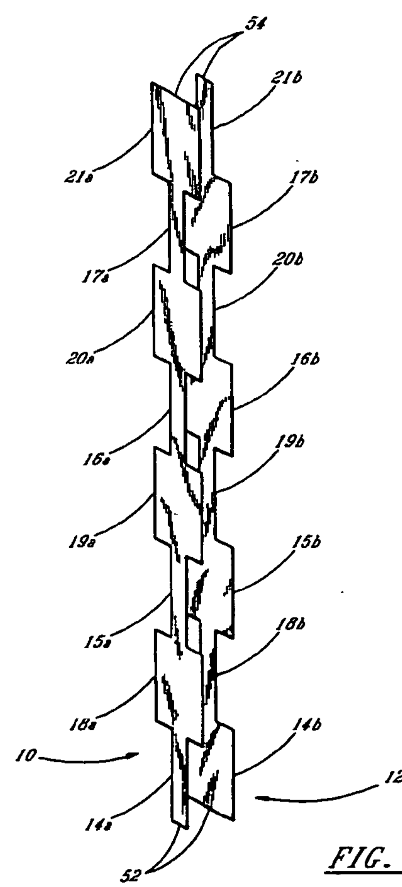


FIG. 1

BACKGROUND OF THE INVENTION

The present invention relates generally to antennas for radio frequency communication and, more particularly, to polarized antennas for radio communication in frequency ranges above about 100 MHz.

DESCRIPTION OF THE RELATED ART

Accurate and cost-effective radio signal transmission is becoming increasingly important in many applications. For example, widespread use of cellular radio communication has significantly raised the stakes in terms of service and sales. Proper antenna design can provide tangible benefits with respect to communication performance and equipment maintenance. These benefits include savings in terms of maintenance costs, equipment utilization, and increased system reliability. Moreover, cost-effective antenna designs provide reduced manufacturing costs and increased sales and profits.

While numerous antenna structures have been designed with the above objectives in mind, each has compromised cost and/or performance. One of the most popular structures, for example, is a sleeved-dipole assembly, which includes a colinear array of dipoles secured to and surrounding a coaxial cable. The dipoles are used to convert the coaxial cable into a radiating transmission line, or antenna. Unfortunately, this type of antenna system is costly to manufacture and maintain due to the number of dipoles and related mounting components.

Accordingly, there is need for an antenna structure which overcomes these deficiencies.

SUMMARY OF THE INVENTION

A general object of the present invention is to provide an improved antenna structure that is reliable, accurate and cost-effective to manufacture and sell.

A more specific object of the present invention is to provide an improved antenna structure that may be manufactured using a pair of opposing sheets of conductive material, which may be punched or etched from a single piece of sheet metal.

These and other objects of the present invention are realized using a first conductive section having alternating wide and narrow portions, and a complementary opposing second conductive section having alternating wide and narrow portions which are arranged opposite the narrow and wide portions, respectively, of the first conductive section. The first and second conductive sections are secured together with a gap formed therebetween such that the first and second conductive sections form an elongated unit having a first end and a second end. A coaxial cable is electrically coupled to the first and second conductive sections for coupling a radio frequency (RF) signal to the antenna. In one embodiment, at least one end of the unit is terminated, and a radome is used to enclose the unit.

Preferably, the unit is terminated by a conductor at only one end, and the other end of the unit is used for interfacing to the coaxial cable.

In another preferred embodiment, the unit is shorted at both ends, and a coaxial cable is electrically coupled to the first and second conductive sections, near the center of the unit, for coupling the radio frequency signal to the antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 is a perspective view of a pair of opposing conductive sections, according to the present invention, which may be used to form an improved antenna structure;

FIG. 2 is a view of the conductive sections of FIG. 1, with one of the sections shown behind the other section and with a coaxial connector shown as an end feed for the antenna structure;

FIG. 3 is a side view of FIG. 2, showing a side view of the coaxial connector of FIG. 2;

FIGS. 4 and 5 illustrate front and side views, respectively, of the conductive sections of FIG. 1, with one of the sections shown behind the other section and with a terminating conductive block at one end;

FIG. 6 is a view of the conductive sections of FIG. 1, with one of the sections shown behind the other section and with a coaxial connector shown as a center feed for the antenna structure, as an alternative to the end feed arrangement of FIG. 2;

FIG. 7 is another illustration of the structure shown in FIG. 6, showing a side view of the conductive sections and the coaxial connector in FIG. 6;

FIG. 8 is an illustration of the elevation patterns of one embodiment of the antenna, according to the present invention; and

FIGS. 9 and 10 comprise a pair of Smith charts illustrating the impedance characteristics of antenna embodiments also in accordance with the present invention.

While the invention is susceptible to various modifications and alternative forms, specific em-

bodiments thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that it is not intended to limit the invention to the particular form described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is directed to radio frequency antenna applications in which signals are transmitted and/or received in the frequency range of about 100 MHz. to 10,000 (or higher) MHz. Some of the intended uses for the present invention concern signal transmission or reception at RF base stations in cellular telephone systems, personal communication network systems (e.g., operating between 1700-1900 MHz.), microwave distribution systems and multipoint distribution systems.

Turning now to the figures and referring first to FIG. 1, opposing conductive sections 10 and 12 are illustrated having a substantially uniform gap therebetween. Each conductive section 10 and 12 includes alternating wide and narrow portions (or elements). For the first conductive section 10, the narrow elements are depicted 14a-17a, and the wide elements are depicted 18a-21a. Conversely, for the second conductive section 12, the wide elements are depicted 14b-17b, and the narrow elements are depicted 18b-21b. The wide elements for the first conductive section 10 are arranged opposite the narrow elements for the second conductive section 12, and vice-versa, to provide radiation from the sections 10 and 12 having a polarization that is parallel to the length of the structure shown.

Each conductive section 10 or 12 is preferably punched or etched from a metallic plate, e.g., a 1/32 inch thick brass plate, so that the two conductive sections may be arranged substantially parallel to one another. Additionally, the wide elements are preferably shaped and arranged in order to inhibit capacitance building up in the gap between the sections 10 and 12. This may be accomplished using obtuse-angled corners forming a non-rectangular shape for each wide element, with top and bottom edges 24 and 26 being rounded or angled. Additionally, a plastic radome is used to enclose the elongated unit comprising the sections 10 and 12, as depicted by 51 of FIG. 2.

As depicted in FIGS. 6 and 7, the gap may be maintained between the first and second conductive sections 10 and 12 using nonconductive screws (or bolts) 30, such as nylon screws, with a spacer 32 separating the sections 10 and 12 and a nut 34 securing the spacer 32. Preferably, such screw-spacer-nut assemblies are located at every other pair of opposing elements 14-21. Alternatively, as illustrated in FIGS. 4 and 5, nonconductive foam-like material 40 with a low dielectric constant may be placed in the gap and adhered to the inside surfaces of the first and second conductive sections 10 and 12, for example, using glue, to maintain the gap therebetween. Such material 40 may be used to fill the gap or may be selectively placed therein to provide the requisite support.

The desired gap may be approximated by viewing each wide and narrow element pair as a microstrip line structure. Thus, with Z_0 as the characteristic impedance in Ohms, W being the width of the narrow conductor, and E_r being the relative dielectric constant of the material in the space between the conductors, the gap spacing would roughly be equal to:

$$[W \times Z_0 \times (\text{square root of } E_r)]/377.$$

A coaxial cable, having a diameter chosen so as not to exceed the width of the narrow element, is preferably electrically coupled to the first and second conductive sections for coupling a radio frequency signal to the antenna of FIG. 1. This coupling may be implemented using end feeding or center feeding. Advantageously, such coaxial cable is preferably run along the sections adjacent and inside the radome; thus, the cable may be an integral part of the antenna structure thereby eliminating the difficulties encountered in coaxial colinear antenna arrays where the feeding cable must not be allowed to re-radiate RF signals and must be electrically isolated from the radiating elements. The present invention therefore obviates the need for RF chokes and/or similar devices required by the prior art. FIGS. 2 and 3 illustrate an end feeding implementation with a conventional SMA coaxial connector 42 coupling the coaxial cable 43 to the sections 10 and 12.

Also illustrated is a tear-drop-shaped extension 44 of the section 10 which may be used as a balanced feeding network to couple energy onto the sections 10 and 12. A narrow portion 45 of the section 12 extends down on the opposite side of the extension 44 so that the inner conductor of the cable 43 may be soldered thereto. Preferably, the outer conductor, via the connector 42, is soldered (or otherwise secured) to the extension 44 in an aperture through the extension 44. Thus, the inner conductor of the cable 43 is exposed in the gap between the sections 10 and 12.

The unit comprising sections 10 and 12 may be terminated using a short or an open at the pair of elements at the end opposite the feeding. Pref-

erably, as illustrated in FIGS. 4 and 5, shorting termination is provided using a conductive rod (or block) 50 electrically connected and secured to the sections 10 and 12. The conductive rod 50 should be located at the center of elements 14a and 14b. Alternatively, an open termination may be implemented simply in the absence of any termination elements.

FIGS. 6 and 7 illustrate center feeding for coupling a radio frequency signal to the antenna of FIG. 1. As in the case of end feeding, a conventional SMA coaxial connector 42 is used to couple the coaxial cable 43 to the sections 10 and 12. In center feeding, however, the coaxial connector 42 is secured directly to the sections 10 and 12, via an aperture through the section 10 centered at the approximate point at which the middle, wide element meets the middle, narrow element.

As with termination for the end feeding structure of FIGS. 2 and 3, termination for the center feeding structure of FIGS. 6 and 7 may be implemented in essentially the same manner, preferably using a conductive rod 50 electrically connected and secured to the sections 10 and 12, as illustrated in FIGS. 4 and 5. However, rather than at only one end of the unit, this termination should be implemented at the centers of the elements at both ends.

The practical bandwidth of the structures shown in FIGS. 1-7 is determined principally by the length of the structure. For maximum gain, the entire structure should be close to resonance. Keeping the antenna gain change within 0.5 dB, the bandwidth for a 6 wavelength long antenna is about 10 percent, and the bandwidth for a 10 wavelength long antenna is about 6 percent.

Two exemplary embodiments operating at a 2300 MHz. center frequency were designed. The first is an end-fed array of six (pairs of) elements, the second is a center-fed array of twelve (pairs of) elements. In calculating various frequency dependent parameters associated with the antenna structures, a center frequency of 2500 Mhz. was used and the length of elements were based on a 100 percent velocity of propagation. The difference between center frequencies was due to the capacitive loading of the wide elements and the dielectric between the antenna halves.

The measured elevation patterns for the 12 element array are illustrated in FIG. 8. The patterns, which are usable over a 10 percent range, exhibit a shape and beamwidth with sidelobes slightly higher than a perfect antenna would have. The measured directivity at 2300 MHz. (using pattern integration) is 8.15 dBd compared with 8.40 dBd of ra perfect antenna of the same aperture. The directivity exceeds 7.4 dBd over a 10 percent bandwidth which is better than competitive antennas with similar directivities.

The Azimuth pattern of the antenna is omnidirectional and will become increasingly oblong as the width of the wide element exceeds four times the width of the narrow element or 0.25 wavelength. The shape of the Azimuth pattern is essentially constant with frequency within a 10 percent band. The element admittance is also important since the sum of the admittances of all elements should be about equal to the characteristic admittance of the antenna structure. This facilitates tuning and improves broadband performance for the pattern and input VSWR. The radiation resistance (that is, the part of the RF energy that is radiated) is dependent on the following factors:

(a) The electrical length of the element (1/2 wavelength is preferred). This implies that the velocity of propagation should in the analogous stripline should be as close to the velocity of propagation on the outside of the structure. While the radome will affect the velocity of propagation, the proper values may be found by alternating the antenna halves, or by using various support elements.

(b) The impedance of the analogous strip-line.

(c) the width of the wide element compared to the narrow one. The wider the wide element is, the more efficient the radiation will be from the element. However, as the width of the wide element exceeds 0.25 wavelength, the Azimuth pattern becomes increasingly oval.

The input impedance of the twelve element array is shown in FIGS. 9 and 10. The process of compressing the impedance variation from that shown on FIG. 9 was achieved by (a) increasing the element admittance by changing the element width from 1 inch to 1.5 inches and final to 2 inches; and (b) by reducing the capacitive loading between elements by shaping the wide element as shown in FIGS. 2, 4 and 6. The final result is such that a simple impedance transformer is all that is needed to produce an input VSWR from about 1.5:1, as shown in FIG. 9 to 1.35:1 as shown FIG. 10.

The following dimensions were used in the embodiments: the gap between the sections 10 and 12 at 0.125 inch, the height of each element, e.g., element 14, at 2.36 inches, the width of the wide elements, e.g., 18a and 15b, at 1.00 inch and the width of the narrow elements, e.g., 18b and 15a, at 0.250 inch.

Accordingly, the present invention provides a cost-effective and accurate antenna structure for RF communication. While the inventive antenna structure has been particularly shown and described with reference to certain embodiments, it will be recognized by those skilled in the art that modifications and changes may be made to the

present invention described above without departing from the spirit and scope thereof.

Claims

1. A radio frequency antenna, comprising:

   a first conductive section having alternating wide and narrow portions:

   an opposing second conductive section having alternating wide and narrow portions which are arranged opposite the narrow and wide portions, respectively, of the first conductive section;

   wherein each portion of the first and second conductive sections has a length which is not greater than about one-half wavelength and wherein the first and second conductive sections are shaped with corners forming an obtuse angle to lessen capacitance therebetween;

   means for securing the first and second conductive sections together with a gap formed therebetween such that the first and second conductive sections form an elongated unit having a first end and a second end;

   a termination conductor means at opposing portions of the first end of the unit;

   coupling means, electrically coupled to the first and second conductive sections at the second end of the unit, for coupling a radio frequency signal to the antenna; and

   a radome substantially enclosing the unit.

2. A radio frequency antenna, comprising:

   a first conductive section having alternating wide and narrow portions;

   an opposing second conductive section having alternating wide and narrow portions which are arranged opposite the narrow and wide portions, respectively, of the first conductive section;

   wherein each portion of the first and second conductive sections has a length which is not greater than one-half wavelength and wherein the first and second conductive sections are shaped using a non-rectangular form and arranged with respect to one another so as to lessen capacitance therebetween;

   means for securing the first and second conductive sections together with a gap formed therebetween such that the first and second conductive sections form an elongated unit having a first end and a second end wherein said means for securing the first and second conductive sections includes non-conductive screws and includes foam-like material having opposing sides respectively adhered to the first and second conductive sections;

   first and second termination conductors respectively at the first and second ends of the unit;

   coupling means, electrically coupled to the first and second conductive sections at about the middle of the elongated unit, for coupling a radio frequency signal to the antenna so as to provide polarization in a direction that is parallel to the direction of the elongation; and

   a radome substantially enclosing the unit.

3. A radio frequency antenna, according to claim 2, wherein the wide portions are each approximately the same size and shape as the other wide portions.

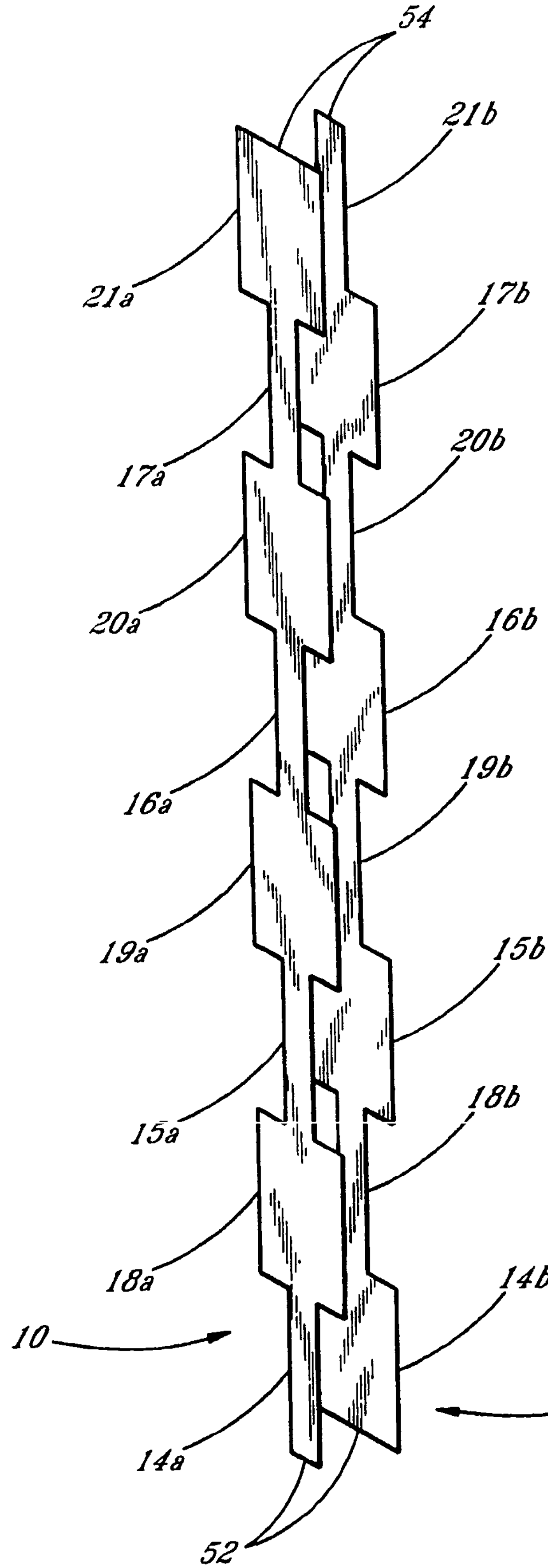

54
21b
21a
17b
17a
20b
20a
16b
16a
19b
19a
15b
15a
18b
18a
14b
10
12
14a
52

FIG. 1

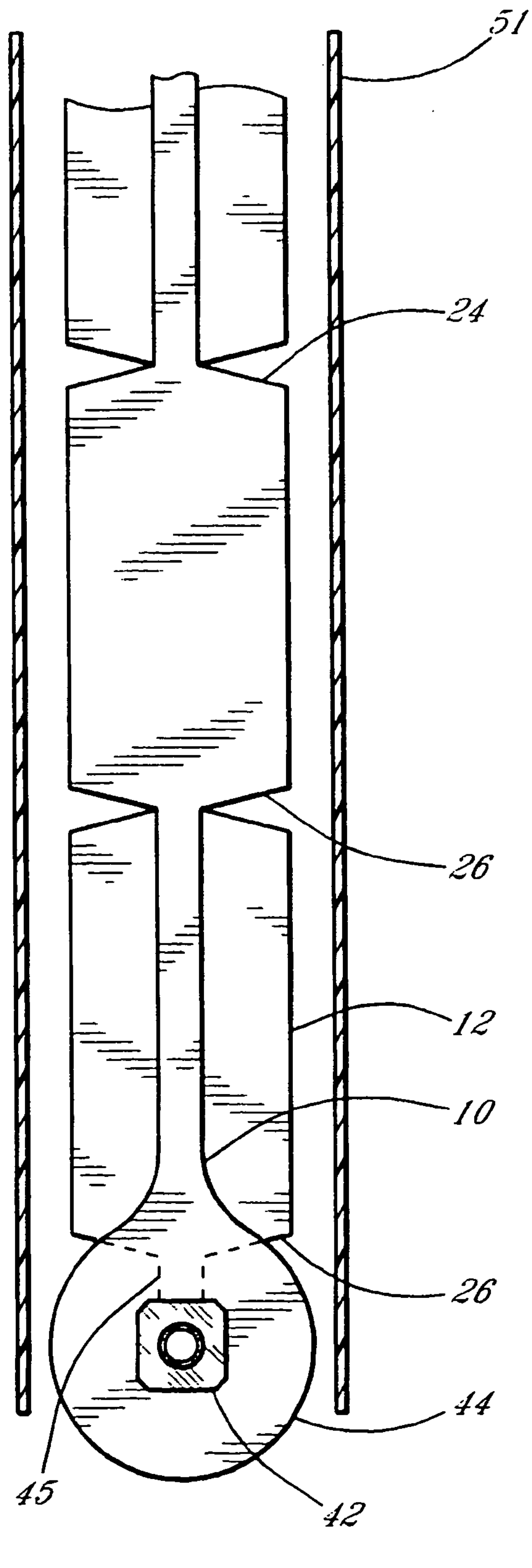


FIG. 2

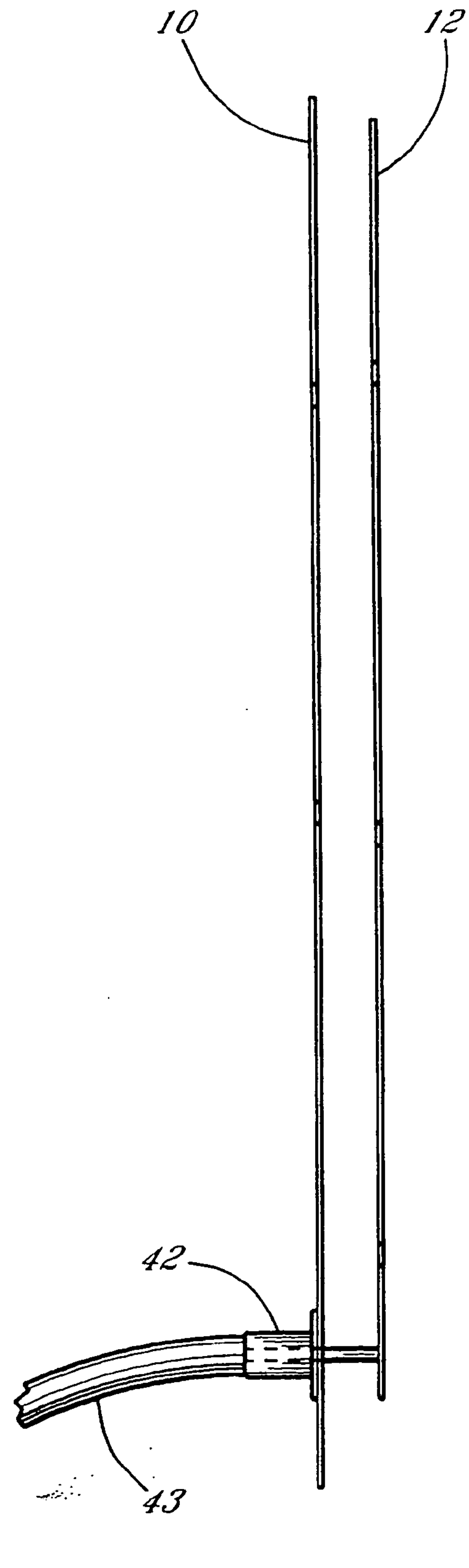


FIG. 3

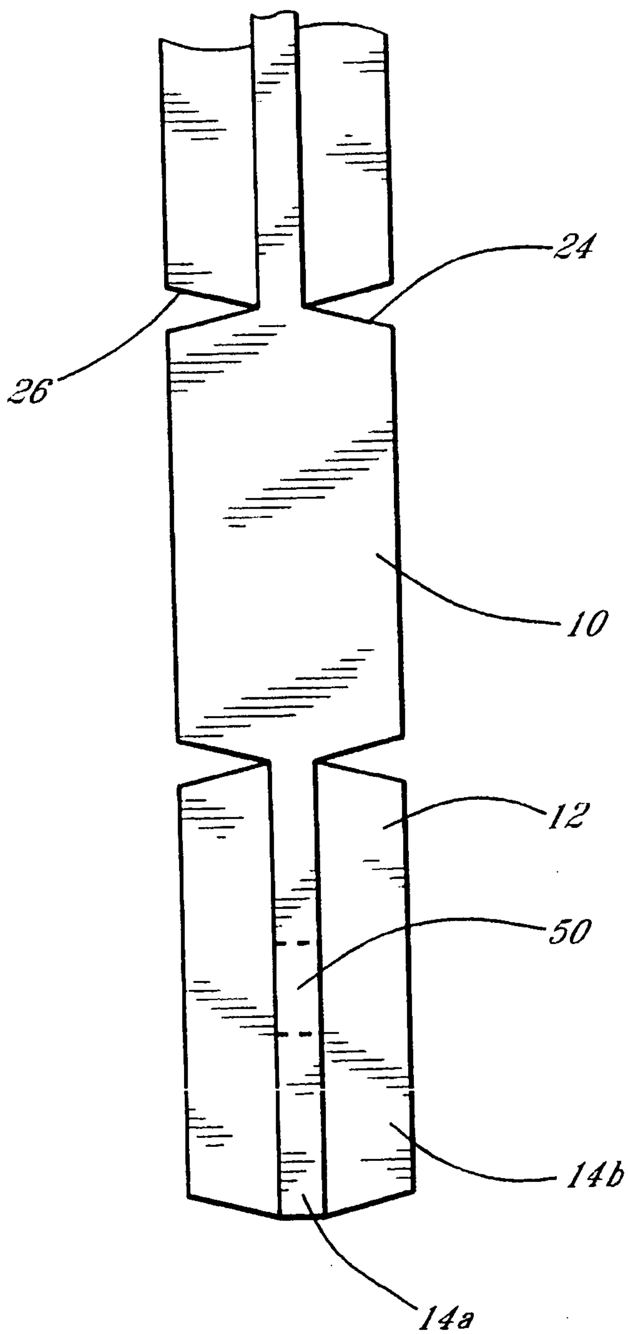


FIG. 4

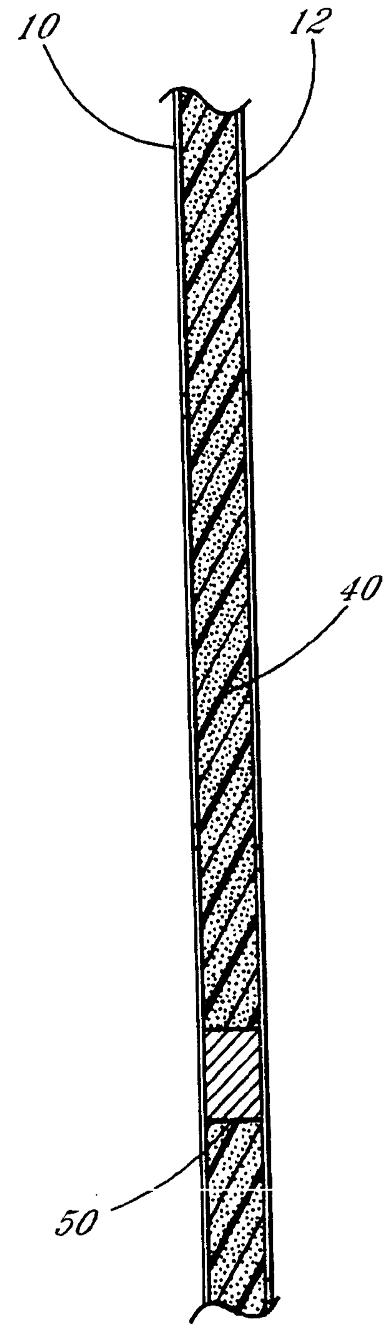


FIG. 5

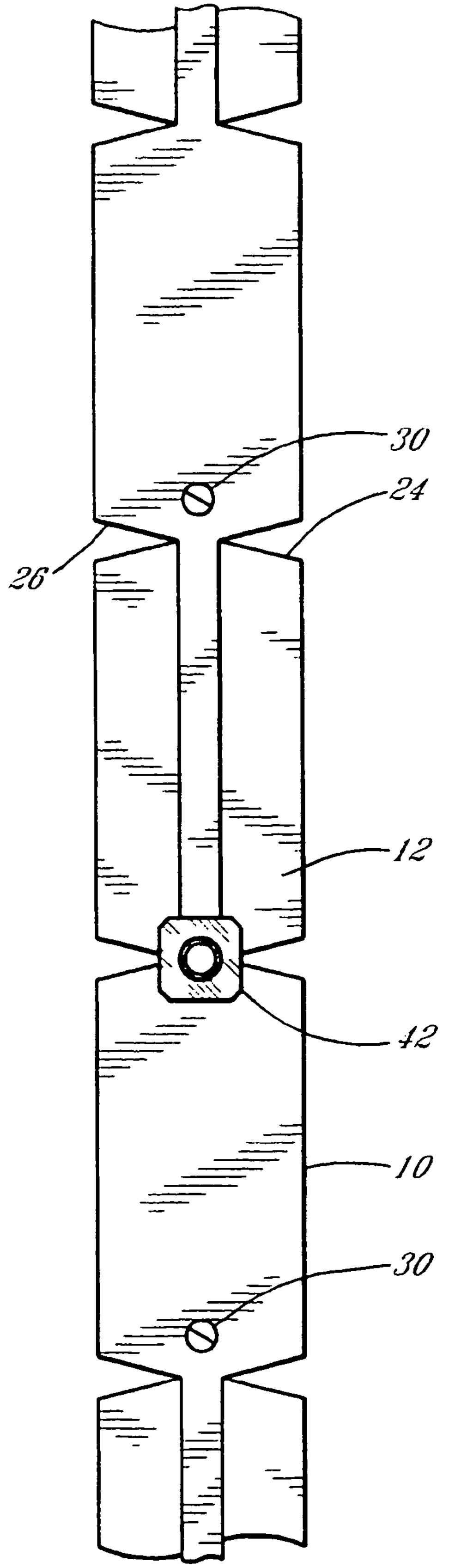


FIG. 6

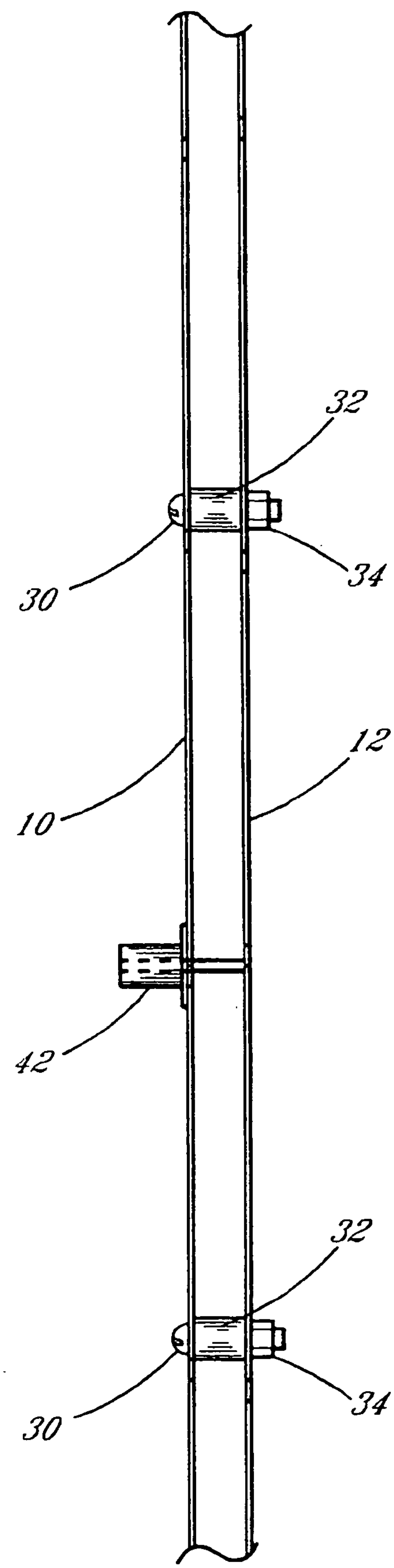


FIG. 7

FIG. 8

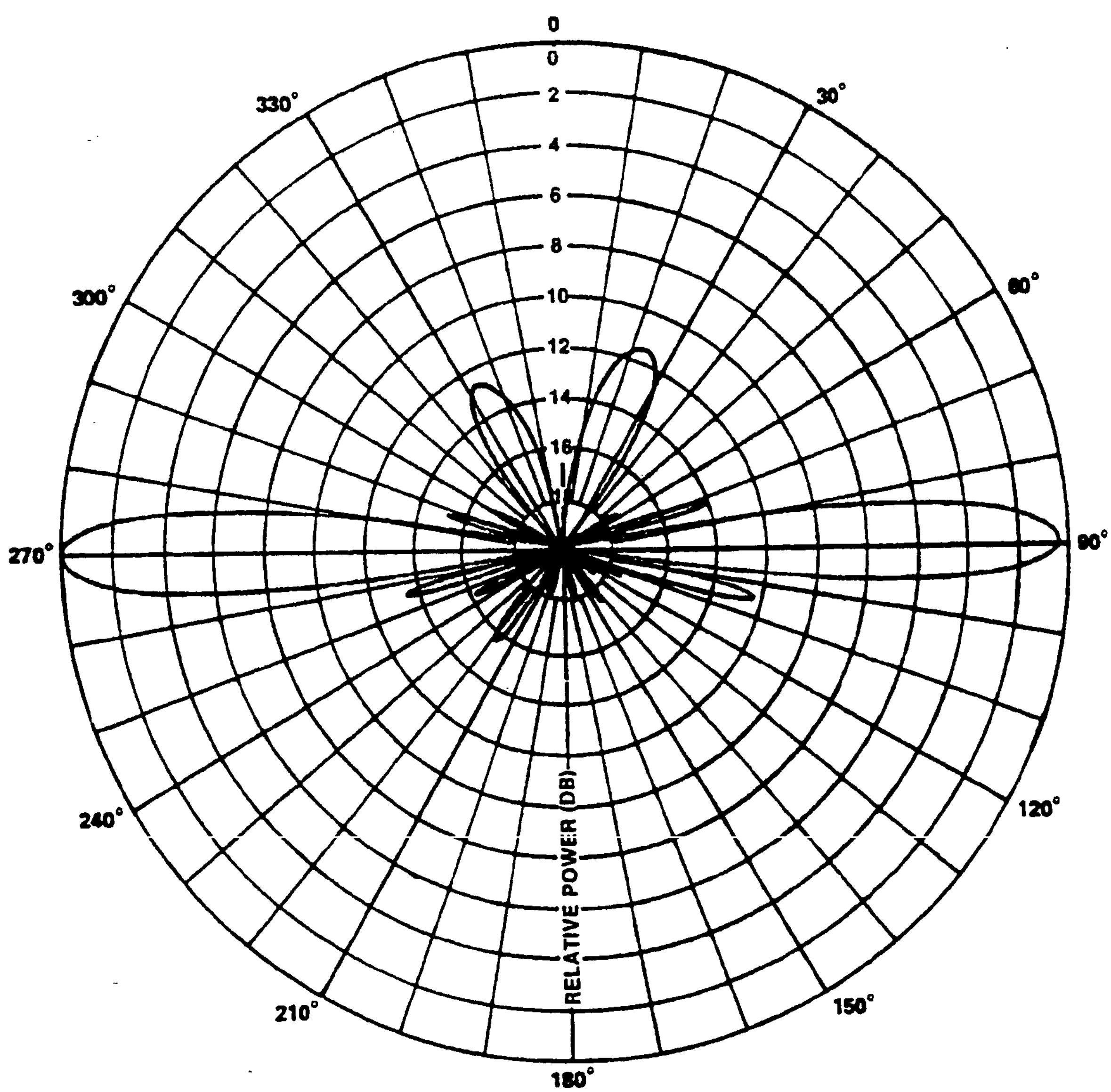

0
0
2
4
6
8
10
12
14
16
330°
30°
300°
60°
270°
90°
240°
120°
210°
150°
180°
RELATIVE POWER (DB)

FIG. 9

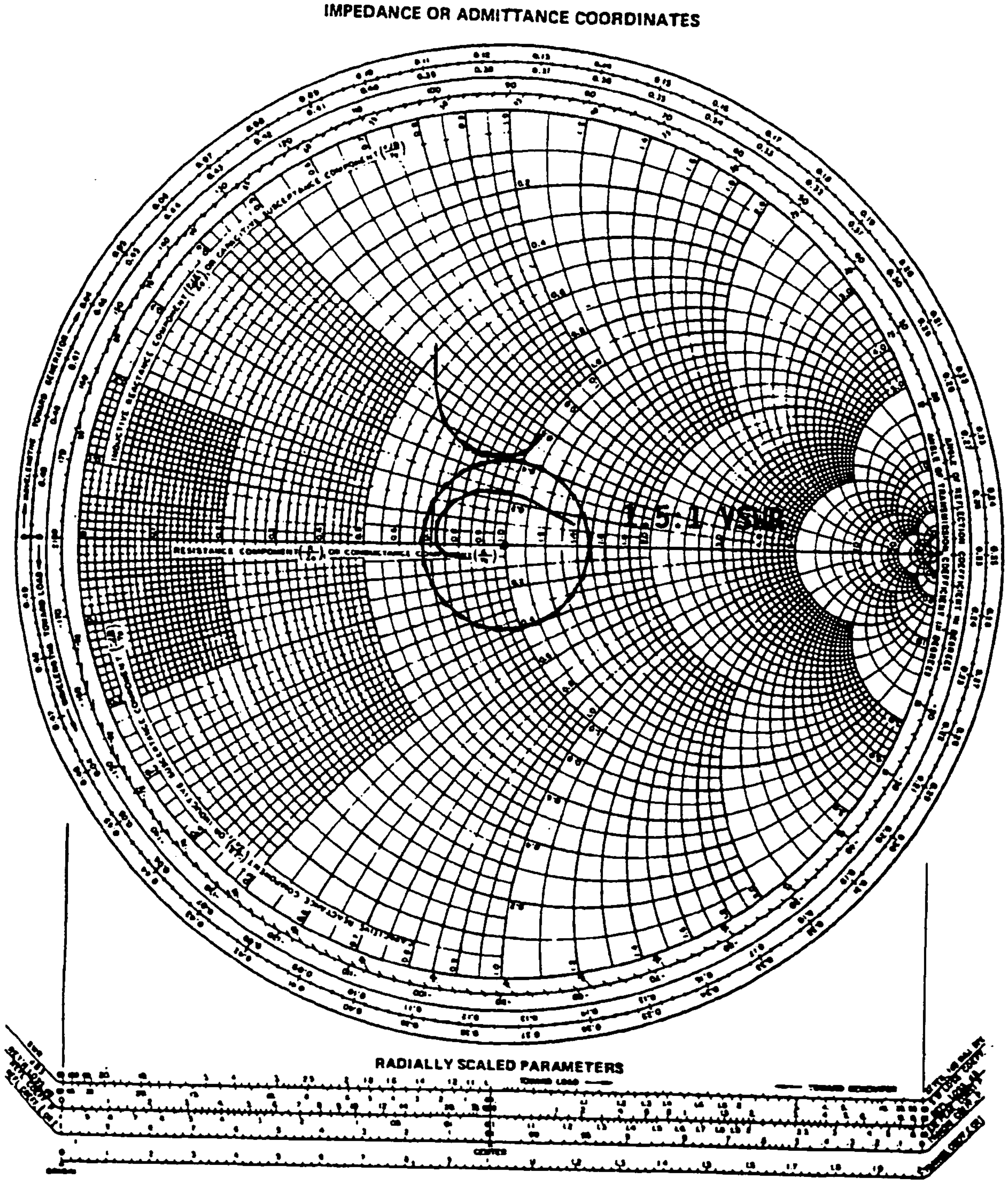
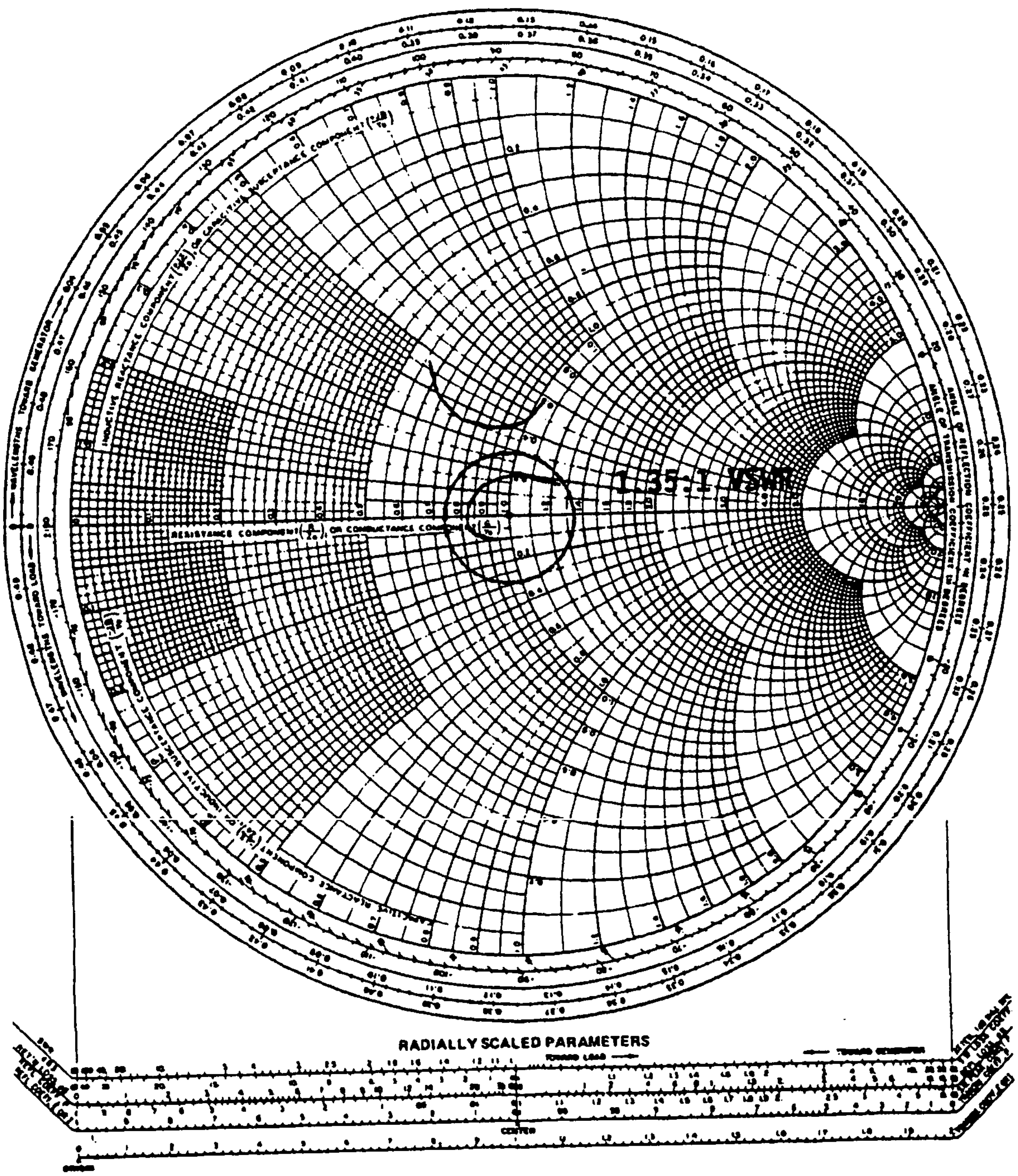

IMPEDANCE OR ADMITTANCE COORDINATES
1.5:1 VSWR
RADIALLY SCALED PARAMETERS

FIG. 10



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EUROPEAN SEARCH REPORT

Application Number

EP 91 11 9764

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	TRANS. INS. ELECTR. & COMM. ENGINEERS OF JAPAN vol. E63, no. 1, January 1980, pages 58-60; M. ONO et al.: "A High-Gain Omnidirectional Antenna Made of a Printed Element" * page 59, figure 1; page 58, right-hand column *	1-3	H 01 Q 1/38
Y	PATENT ABSTRACTS OF JAPAN vol. 3, no. 60 (26)(E-112), 23 May 1979; & JP - A - 5437663 (MITSUBISHI DENKI) 20.03.1979	1,2	
Y	PATENT ABSTRACTS OF JAPAN vol. 1, no. 35 (1864)(E-76), 15 April 1977; & JP - A - 51132058 (MITSUBISHI DENKI) 16.11.1976	1,2	
A	GB-A-2 142 475 (DECCA) * figures 1,2; column 1, line 112 - column 2, line 92 *	1-3	
A	DE-A-2 632 772 (LICENTIA PATENT-VERWALTUNGS-GMBH) * figure 1; claim 7 *	2	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	PATENT ABSTRACTS OF JAPAN vol. 3, no. 66 (2)(E-115) 7 June 1979; & JP - A - 5443446 (MITSUBISHI DENKI) 04.06.1979		H 01 Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	29-01-1992	BEITNER M.J.J.B.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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E : earlier patent document, but published on, or after the filing date
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